

HAZARDOUS WEATHER PHENOMENA

Airframe Icing

Bureau of Meteorology › Weather Services › Aviation



Accumulation of ice on aircraft is one of the most significant hazards to the safe and efficient operation of aircraft as it can reduce aircraft performance in a number of ways. Aircraft flying through cloud in sub-freezing temperatures are likely to experience some degree of icing.



Introduction

In-flight icing is a serious hazard to aircraft because it can:

- increase the stall speed of the aircraft by increasing its weight and changing the aerodynamics of the wing and tail
- make it almost impossible to operate control surfaces and landing gear
- destroy the smooth flow of air over the aircraft
- increase drag and decrease lift (tests have shown that icing no thicker or rougher than a piece of coarse sandpaper can reduce lift by 30% and increase drag by 40%)
- cause engine failure
- cause propeller vibrations
- damage compressor blades of jet engines (chunks of ice can inject into the engine)
- produce errors in instrument readings of air speed, altitude and vertical speed
- interfere with communications systems
- reduce visibility

Aircraft flying through cloud in sub-freezing temperatures are likely to experience some degree of icing. A pilot can reduce the chance of icing becoming a serious problem by selecting appropriate flight routes, remaining alert to the possibility of ice formation and knowing how and when to operate de-icing and anti-icing equipment.

The risk of an icing encounter can be evaluated by considering the air temperature, and the number and size of water droplets. The more liquid water there is, the higher is the potential for severe icing. More icing incidents in Australia occur during the winter months than at other times of the year.

The three types of aircraft icing are structural (airframe), induction and instrument icing. Aviation weather forecasts are only concerned with structural icing, which is ice accumulation on the exterior parts of the airframe. It occurs when water droplets (cloud or liquid precipitation) at temperatures below the freezing point (i.e. they are supercooled) freeze on impact with aircraft surfaces.



SIGMET will be issued for severe icing. Area Forecasts will include any expectation of moderate or severe icing.

While this brochure deals with the meteorological aspects of structural icing, it is important to note that many non-meteorological factors will influence the rate of ice accretion. For example, the length of time spent within icing conditions, the aircraft shape, the speed of the aircraft and the type (if any) of de-icing/anti-icing equipment on board the aircraft. Therefore it can be difficult to correctly identify the threat that icing conditions will pose on any particular aircraft.

Icing Severity Classification

Icing severity is generally classified as trace, light, moderate or severe. **Trace** is used when the rate of accumulation is slightly greater than rate of sublimation (the process of ice changing directly to vapour, bypassing the liquid phase) resulting in the ice becoming perceptible. It is not hazardous and de-icing/anti-icing equipment is not utilized unless encountered for an extended period of time (i.e. over one hour). **Light** means the rate of accumulation may create a problem if flight is prolonged in the environment (i.e. more than one hour). Occasional use of de-icing/anti-icing equipment removes or prevents accumulation. It does not present a problem if the de-icing/anti-icing equipment is used. **Moderate** means the rate of accumulation is such that even short encounters become potentially hazardous and use of de-icing/anti-icing equipment or diversion is necessary. **Severe** means the rate of accumulation is such that de-icing/anti-icing equipment fails to reduce or control the hazard, and thus an immediate diversion is necessary.

Icing Types

Icing conditions are only present in temperatures between 0°C and -40°C, with the highest risk occurring between 0°C and -15°C. The size and temperature of the supercooled water droplets that impact on the aircraft determine the category of ice that is formed.

Rime ice is formed by small water droplets freezing quickly upon impact, trapping air inside the ice, giving it a white, opaque and lumpy appearance. Because this ice freezes quickly, it is usually confined to the leading edge of the wing. It may be encountered anywhere between 0°C and -40°C, but most frequently forms in the temperature range of -10°C to -20°C in stratiform clouds, although cumuliform clouds may also produce rime at temperatures below -10°C. Much of it can be removed by de-icing and prevented by anti-icing.

Clear (or glaze) ice is formed by larger water droplets that freeze more slowly upon impact, enabling the ice to extend further along the surface, initially producing a smooth sheet of transparent ice, but after further accumulation it can form ridges. Clear ice forms most readily in temperatures between 0°C and -10°C but can occur, with reduced intensity, at lower temperatures. It is most commonly experienced in cumuliform cloud where large supercooled water droplets are often encountered, and below cloud in freezing precipitation. The latter can result in the most severe forms of clear icing when an aircraft below the cloud base encounters the supercooled rain or drizzle, which may result in an aircraft becoming enshrouded in a clear ice layer in a matter of seconds. Such conditions can occur ahead of a warm front or sometimes behind a cold front when warm moist air aloft overruns sub-zero air at lower levels. Rain falling from or through the warm air into sub-zero air can become supercooled. On impact with an aircraft the supercooled raindrops flow over exposed surfaces and freeze as clear ice.

Mixed ice, a combination of clear ice and rime ice, is the most frequent form of icing because different sized water droplets commonly occur in cloud. It is most likely to form in the temperature range of -10°C to -15°C. It is formed when the water droplets vary in size or are mixed with snow, ice pellets or small hail.

Hoar frost, another type of icing, is not specific to a particular temperature range. It is a white, feathery crystalline deposit which can occur in clear air when an aircraft passes quickly from sub-zero dry air to warm moist air, with the water vapour in the



Anti-icing prior to flight



Anvil of a cumulonimbus cloud



Towering cumulus cloud



Nimbostratus cloud



Stratocumulus cloud



Alto cumulus cloud

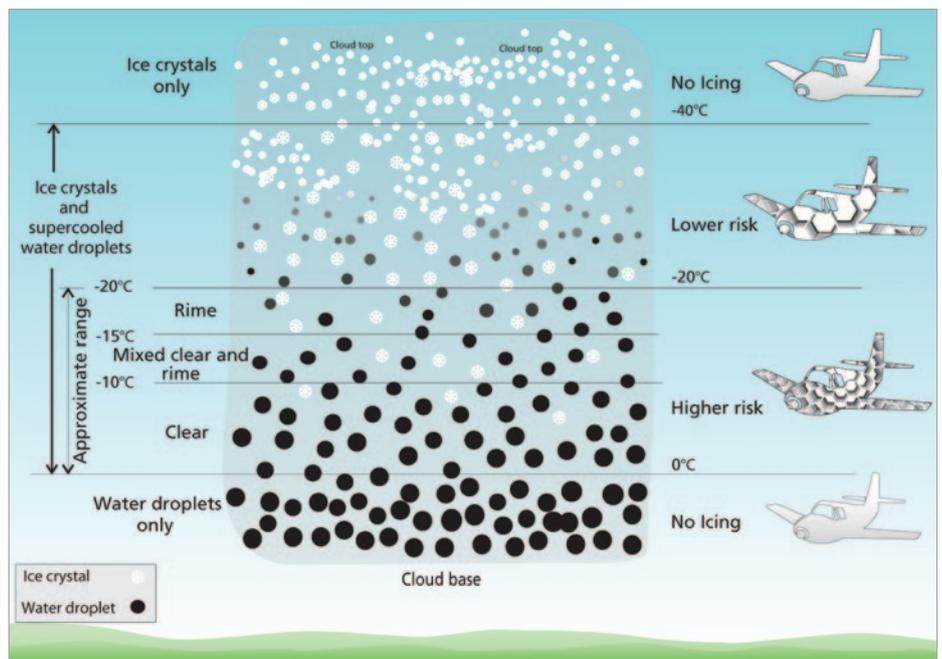
Structural icing in high-level cloud such as cirrus is unlikely to be a problem as these are usually composed of ice crystals, which will not freeze on to the airframe.

warmer air changing directly to ice. It can, for example, occur on a frosty, calm morning when an aircraft, which has cooled to below freezing, takes off into warmer, moister air causing the water vapour to deposit as ice on the windscreen and canopy. The ice will quickly disappear if the aircraft remains in the warmer environment, however it can cause significant problems in the interim period, with the build-up on the greatly reducing visibility. It can disrupt the smooth airflow over the wing, inducing early separation of the airflow over the upper surface. Hoar frost can also occur on parked aircraft when the temperature is sub-zero and the humidity is close to saturation point.

The Icing Environment

The distribution of supercooled water droplets and ice within a cloud varies with temperature. In general the largest supercooled droplets are found at temperatures just below 0°C, i.e. at altitudes just above the freezing level (FZL). The size of the supercooled droplets tends to decrease with decreasing temperatures and/or increasing altitude.

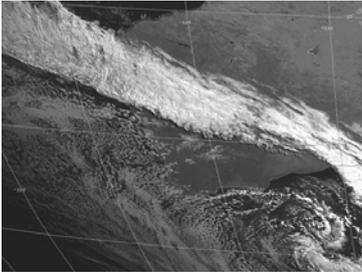
The rate of ice accumulation is directly proportional to the amount of supercooled liquid water present. In clouds, the worst-case scenario is most likely to occur in towering cumulus and cumulonimbus because of their vertical extent, the abundant supply of moisture and the large droplet size found them.



Droplet size and concentration are characteristic of different cloud types. The broad relationship between cloud type and icing are:

Code	Cloud Type	Icing threat
CB	Cumulonimbus	Possible severe clear ice
TCU	Towering cumulus	Possible severe clear ice
NS	Nimbostratus	Moderate mixed icing in lower levels.
SC	Stratocumulus	Moderate rime when freezing level is low enough
AS	Altostratus	Light to moderate rime. Clear ice possible in lower levels.
AC	Alto cumulus	Light to moderate rime
ST	Stratus	Nil to light rime

Synoptic weather patterns govern the movement and overall location of icing environments.



Northwest cloud band

Cloud-Producing Systems

Cloud formation and subsequent icing is most likely to occur in systems with enhanced upmotion such as:

Active fronts which force one air mass up and over another. Although the lifting over a moving cold air mass can have a broad extent, the more intense lifting caused by a cold front tends to be limited to narrow bands of clouds tens of kilometres wide near the surface frontal location. Fronts in general can be areas of enhanced icing due to the presence of convection and ample moisture.

Cyclonic circulations generate convergence of air near the centres of low-pressure systems, producing large-scale (over hundreds or even thousands of kilometres) rising motion and resultant cloud formation. The extensive nature, both vertically and horizontally, of a synoptic-scale cyclone can result in long exposures of aircraft to icing conditions.

Orographic lifting over hills or mountains is likely to increase both the depth of a cloud layer and the liquid concentration within the cloud. Icing may therefore occur more rapidly in elevated areas. The severity will be increased if frontal systems are also in the vicinity.

Warm Air Advection, often associated with poleward moving air, results in large-scale upmotion. Cloud resulting from warm air advection is most recognisable in the form of a northwest cloud band. Icing can be severe due to its widespread nature and with upmotion providing a constant supply of liquid water.

Detection & Monitoring

No tools currently exist for pilots to readily identify and monitor icing conditions, other than first hand experience. However, current and forecast icing risk may be inferred using the information provided in this brochure in conjunction with the forecasts, warnings & observations provided by the Bureau of Meteorology. Pilots should keep in mind that the prerequisites for airframe icing are:

- Aircraft flying through visible supercooled cloud or precipitation.
- Airframe at zero or sub-zero temperature.

A pilot in command of an aircraft must advise Air Traffic Services promptly of any hazardous weather encountered or observed. Whenever practicable, those observations should include as much detail as possible, including location and severity. Hazardous weather includes thunderstorms, severe turbulence, hail, icing, line squalls, and volcanic ash cloud. Moreover, a pilot in command should make a special AIREP report when requested or as soon as practicable after encountering any SIGMET phenomenon, or any other meteorological condition likely to affect the safety or markedly affect the efficiency of other aircraft.

Forecasts & Warnings

The Bureau of Meteorology provides a number of forecasts and warnings containing information on the timing, severity and extent of icing conditions. These include:

- SIGWX Charts – both mid and high level charts contain icing forecasts in a graphical format.
- Area Forecasts – provides an icing forecast based on cloud type, temperature and synoptic-scale influences.
- SIGMETs – provides warning of areas (horizontal and vertical extent) expected to contain severe icing conditions, either observed or forecast.



Australian Government
Bureau of Meteorology

Airservices Australia is the official distributor of aviation forecasts, warnings and observations issued by the Bureau of Meteorology. Airservices' flight briefing services are available at www.airservicesaustralia.com. Telephone contact details for elaborative briefings are contained in Airservices' Aeronautical Information Publication Australia (AIP), which is available online through their website.

Other brochures produced by the Bureau of Meteorology's aviation weather services program can be found at www.bom.gov.au/aviation/knowledge-centre.